THE APPLICATION OF LOCAL CANE SUGAR AS TYPE D CONCRETE ADMIXTURE

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ABSTRACT

The achieved compressive concrete strength is greatly affected by its workability in the fresh state, that is the ability of concrete to be easily transported, placed and compacted. However, lower water-cement ratio has normally inadequate workability, which is reflected in its low slump value. For higher water-cement ratio the workability of concrete can also decrease if longer time is needed before it is placed and compacted or if the ambient temperature is quite high. Therefore an admixture is commonly used to improve and or to maintain the concrete workability. This paper discusses the application of local cane sugar produced by Madukismo, Yogyakarta, Indonesia as an alternative of such admixture, known as Type D according to ASTM Standard C494. In the experiment the following water-cement ratio of 0.33, 0.36, 0.43, 0.46, 0.53, 0.56, 0.63, and 0.66 were used. The variations of cane sugar content for each water-cement ratio were 0%, 0.05%, 0.15%, and 0.20%. From the test results it was found that the application of local cane sugar remarkably increases and maintains the concrete workability in terms of slump value. It is also noted that the achieved compressive concrete strengths are greater than the ones without sugar content. Therefore cane sugar can be used as Type D concrete admixture.

INTRODUCTION

The compressive strength of concrete of a given mix proportion is very seriously affected by its fresh state properties. Therefore, it is important that the consistence or the workability of the mix be such that the concrete can be transported, placed and finished sufficiently easily and without segregation and bleeding [Neville (1975), Gambhir (1986)]. One way to indicate the workability of concrete is by conducting a slump test as shown in Figure 1, where the mould for this test is depicted in Figure 2. Concrete with a high slump normally indicates that the concrete has a high degree of workability such as shown in Figure 1.a.

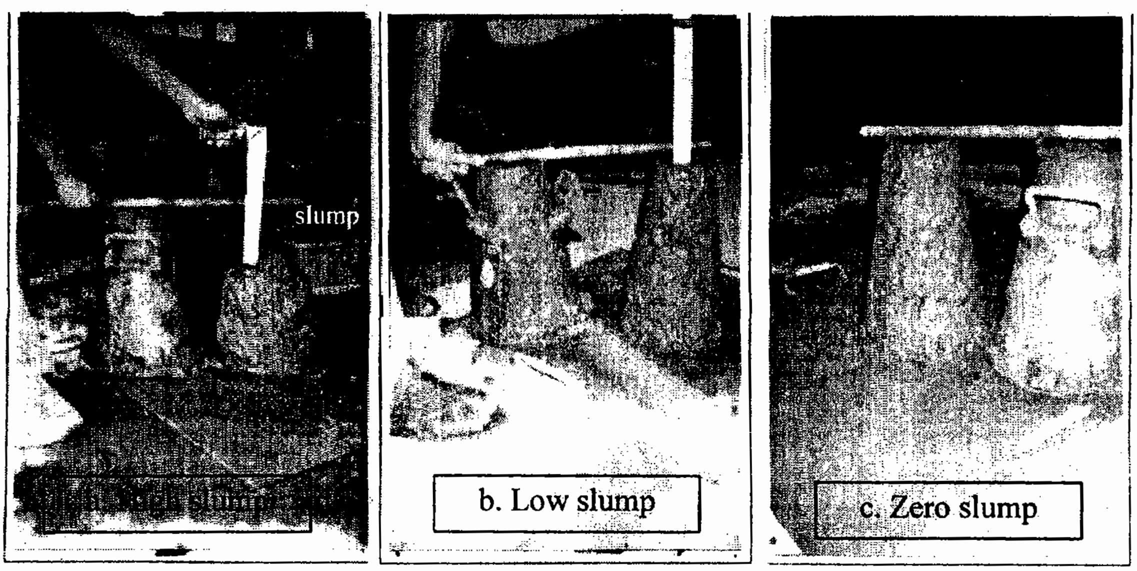

Figure 1. Slump test to indicate concrete workability.

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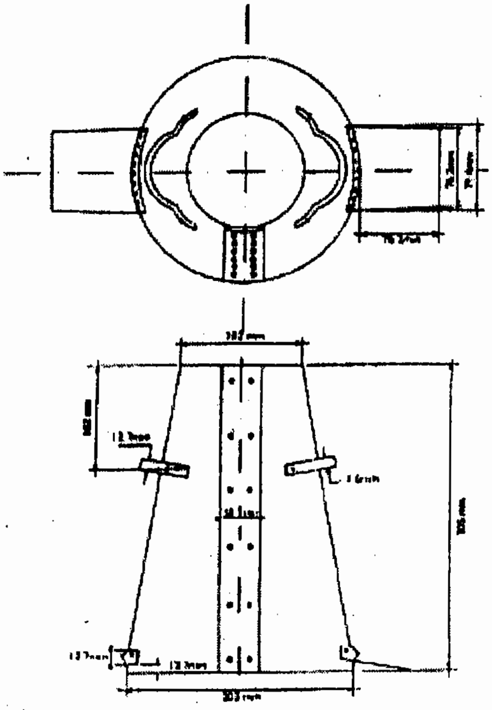

Figure 2. Mould for the slump test.

Concrete with low water-cement ratio normally has low slump, and hence has low degree of workability. For higher water-cement ratio the workability of concrete can also decrease if longer time is needed before it is placed and compacted or if the ambient temperature is quite high [ACPA (1975)]. In this case the initial concrete slump is high, but could become zero in about an hour later. To improve and to maintain the concrete slump, an admixture that can work as a plasticizer and as a retarder is to be added in the concrete mix. In the market such type of admixture is classified as Type D according to ASTM C 494.

In a series of setting time test using Vicat apparatus, Satyarno et.al. (2003) found that local cane sugar produced by Madukismo significantly increase the setting time. The setting time can be increased from about 2 hours for normal cement paste to about 18 hours for the cement paste with sugar content of 0.20%. Based on this result, the application of local cane sugar is extended to be used in concrete as an admixture to see the possibility of using this material as an alternative of Type D admixture sold in the market.

THEORY

The two main groups of Type D admixtures are as follows [Neville (1975)].

1. Lignosulphonic acids and their salts, which is known as Class 1 according to ASTM nomenclature, that is air-entraining admixtures.
2. Hydroxylated carboxylic acids and their salts, which is known as Class 3, that is retarding admixtures.

The modifications and derivatives of these, known as Class 2 and 4 or water reducing admixtures and accelerating admixtures respectively, do not act as a retarder. They may even behave as accelerators, that is Type A or E.

Sugar in general term applied to any of a number of chemical compounds in the carbohydrate group that are readily soluble in water which are odorless, colourless, crystallizable and are more or less sweet in taste. Many term of sugar such as disaccharide sugars, maltose, lactose, and sucrose, have the empirical formula $C_{12}H_{22}O_{11}$. Among the commercially important sugars are glucose, lactose, maltose, and sucrose. Sucrose is generally known as saccharose or cane sugar that can be used as a retarder. This is because retarders are commonly based on chemical composition such as lignosulfonic acids and their salts, hydroxy-carboxylic acids and their salts, sugars and their derivatives, and inorganic salts. The application of cane sugar as concrete admixture has been previously studied by Thomas (1921), Hansen (1952), Gonnerman (1938-1939), Ashworth (1965), and Young (1972).

EXPERIMENTAL WORKS

The scope of experimental works discussed in this paper are the effect of cane sugar on concrete workability and compressive strength. The materials, apparatus and parameters applied in the experiment are explained as follows. More detail explanation of the experiment can be found in Satyarno et.al. (2003).

Materials

The materials used in the experiment are:

1. water,
2. Type I Portland Cement of Nusantara,
3. cane sugar produced by Madukismo, Yogyakarta, which was ground to become powder,
4. fine aggregate from Progo River Yogyakarta,
5. crushed coarse aggregate from Purworejo, where the maximum diameter is 20 mm .

Apparatus

The main apparatus used in this research are as follows:

1. a set of sieve shaker,
2. concrete mixer,
3. concrete cylinder mould,
4. mould for the slump test,
5. Los Angles machine,
6. Universal Testing Machine,
7. other supporting apparatus such as caliper, weighing, stopwatch and spoon.

Procedure

To see the effect of cane sugar on the fresh and hardened concrete the following water-cement ratios were used 0.33, 0.36, 0.43, 0.46, 0.53, 0.56, 0.63, and 0.66. It is noted here that water-cement ratio is the ratio in weight of the applied water and cement in the mix. The variation of cane sugar content for each water-cement ratio were 0%, 0.05%, 0.15%, and 0.20%. Slump tests were carried out to examine the fresh concrete workability and compressive cylinder tests were carried out to find the compressive concrete strength. The design slump for the whole variations of water-cement and cane sugar content were 30 – 60 mm. Nine concrete cylinders were made for each water-cement ratio and each cane sugar content. The first three cylinders were for compressive tests at 7 days, the second three cylinders were for compressive tests at 28 days. The last three cylinders were for slump test series, where the concrete was put in the moulds for compressive test at 28 days when the slump was already zero. Therefore a total of 288 concrete cylinders were made. The mix design of concrete is based on Indonesian Standard [SNI 03-2834-1992, Pandarangga and Satyarno (2002)].

The concrete mix design in brief can be explained as follows. The proportion of fine and coarse aggregate was determined to reach the most compact aggregate, hence a minimum void or air content. In this research the maximum aggregate diameter is 20 mm, and the proportion of fine and coarse aggregate was determined by the computer program [Pandarangga and Satyarno (2002)] to fit the intended curve using the combination of modulus of fines between 5.04 to 5.44, that is between curve no. 3 and no. 2. The water was taken 200 litres per m^3 so that concrete mix design for each water-cement ratio is as shown in Table 1.

Table 1. Concrete mix design.

w.c.r	Water (l)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
0.33	200	606	646	968
0.36	200	556	666	998
0.43	200	465	792	968
0.46	200	435	806	985
0.53	200	378	737	1106
0.56	200	357	745	1118
0.63	200	317	761	1142
0.66	200	303	863	1054

w.c.r = water cement ratio in weight

Table 2. Slump test results.

Period (minute)	Slump (mm) for various water-cement ratio and cane sugar content (%)															
	0.33				0.36				0.43				0.46			
	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)
0	17	19	38	24	14	59	72	104	38	53	73	81	29	79	79	91
30	4	9	15	11	0	21	53	52	6	25	26	45	4	35	35	61
60	0	0	12	10		13	22	42	0	16	16	23	0	16	21	25
90			11	4		3	16	14		7	11	16		15	16	23
120			8	3		0	3	16		3	6	8		6	6	12
150			0	3			0	10		0	0	4		0	0	8
180				0				0				0				7
210																0
240																
270																

Period (minute)	Slump (mm) for various water-cement ratio and cane sugar content (%)															
	0.53				0.56				0.63				0.66			
	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)	0.00 (%)	0.05 (%)	0.15 (%)	0.20 (%)
0	49	87	102	97	27	35	80	93	13	35	70	76	11	26	31	51
30	13	68	79	57	12	32	60	57	9	26	68	51	4	13	24	35
60	0	29	62	49	5	17	41	51	5	20	34	47	0	9	12	19
90		14	41	28	0	10	27	35	0	10	16	30		5	3	13
120		0	36	25		9	25	27		8	16	13		0	2	8
150			21	12		8	10	20		2	6	16			0	2
180			18	5		0	5	10		0	6	12				0
210			10	0			0	7			0	8				
240			0					0				2				
270												0				

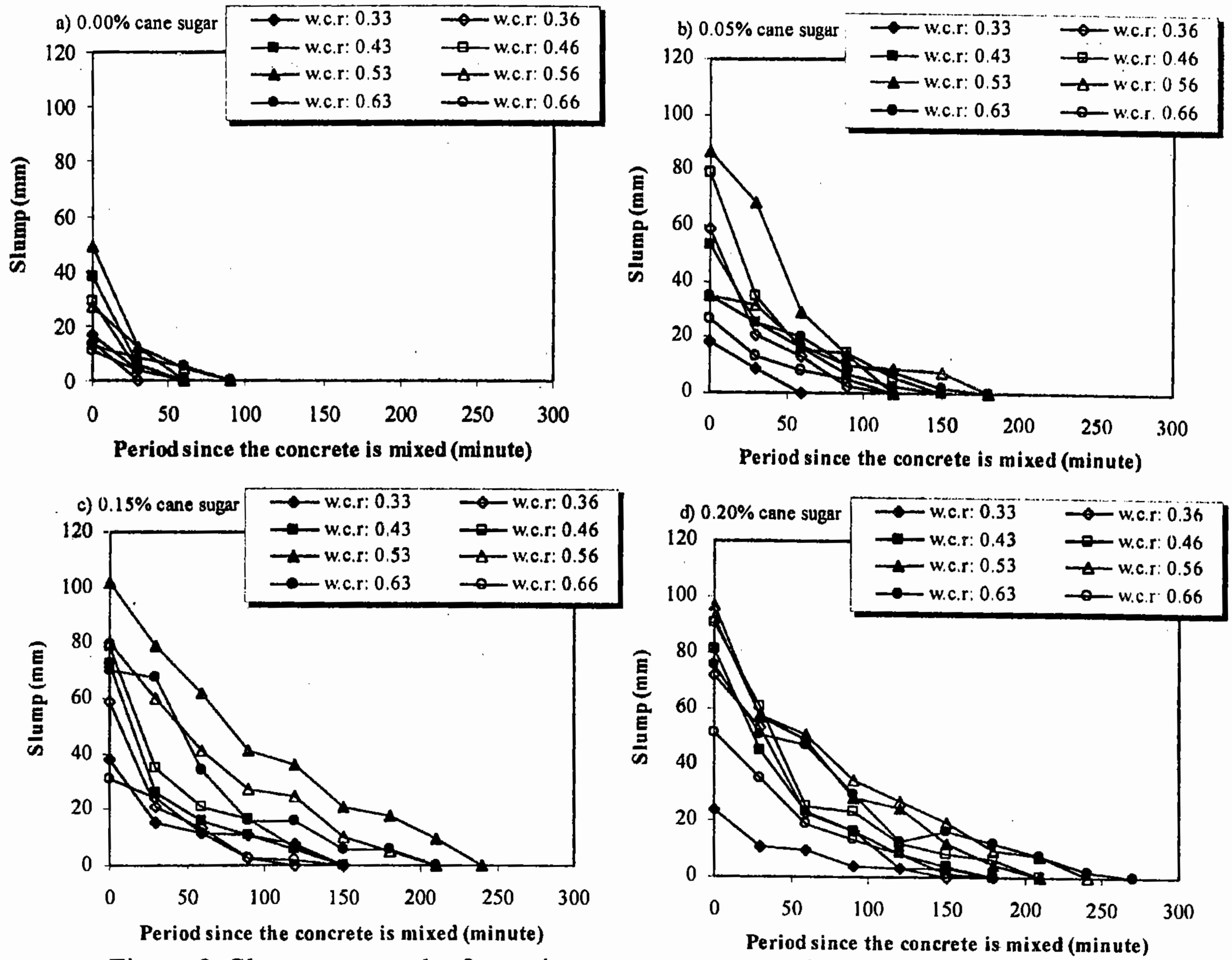

Figure 3. Slump test results for various water cement ratio and cane sugar content.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The experimental results and discussions explained in this paper are divided into three parts, they are workability, compressive strength, and compressive strength gain as follows.

Workability

Table 2 and Figure 3 show the results of average slump tests of three readings for each period, water-cement ratio, and cane sugar content. It is clear that the application of local sugar cane has the following effects on concrete workability:

1. to increase the concrete slump,
2. to lengthen the workability period.

The increment of slump is quite significant as it can reach as much as 500 % for cane sugar content of 0.20% as can be seen in Figure 4. From Figure 3 it is also noted that the workability period is also greatly increased. In this case the workability period is defined as the required period to reach zero slump since the materials were mixed. If the workability period of concrete without cane sugar content is maximum only around 90 minutes, the workability period can be lengthened to around 270 minutes for the cane sugar content of 0.20%.

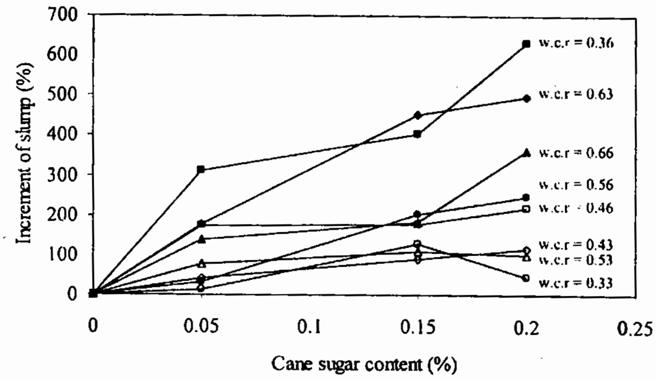

Figure 4. The increment of slump as the increment of cane sugar content.

Compressive Strength

The achieved compressive strength for various water-cement ratio, cane sugar content, and concrete age is presented in Table 3. The increment of compressive strength in percent from the concrete without cane sugar content are depicted in Figures 5 to 7. From these figures it can be seen that the application of cane sugar in general increases the compressive strength, although in rare cases the application of cane sugar seems to decrease the compressive strength. The increment of compressive strength can reach as much as 66% at the age of 7 days and 50% at the age of 28 days.

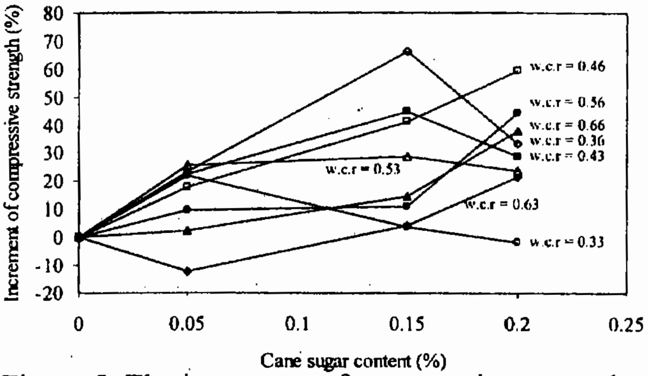

Figure 5. The increment of compressive strength at 7 days.

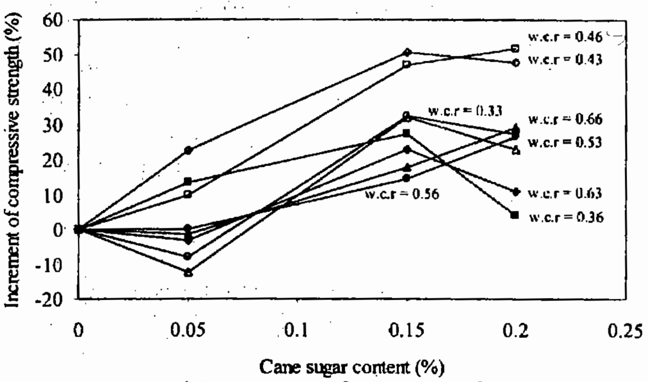

Figure 6. The increment of compressive strength at 28 days.

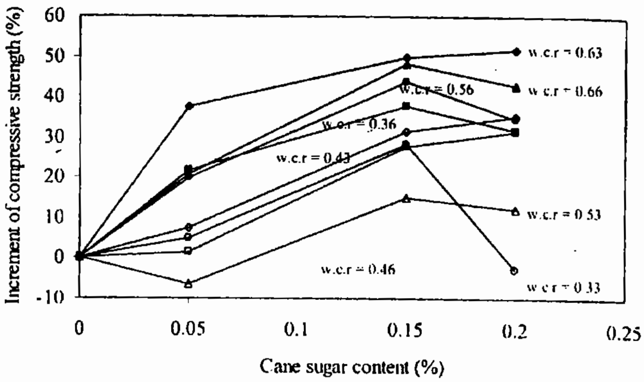

Figure 7. The increment of compressive strength at 28 days, where the concrete was poured after it has reached zero slump.

Compressive Strength Gain

One of some considerations that should be taken in the application of a retarder admixture is the compressive strength gain. As the retarder delays the process of hydration, a slower gain of compressive strength should be anticipated. For normal concrete, the ratio of concrete strength at 7 days to 28 days is around 0.67 [Neville (1975), Mindess and Young (1981)]. Therefore it is also important to investigate this ratio for concrete with sugar content as shown in Table 4. From this table it can be seen that the application of cane sugar does not significantly influence the compressive strength gain. This is because most of the ratio of the compressive strength at 7 days to the one at 28 days are mostly around 0.67, some are even more than 0.67.

Table 3: Compressive strength (MPa) for different water-cement ratio, cane sugar content and age.

Case	Water-cement ratio							
	0,33	0,36	0,43	0,46	0,53	0,56	0,63	0,66
C-0.00-7	44	36	30	30	25	23	21	18
C-0.00-28	54	45	38	37	35	36	28	23
C-0.00-28-Z	56	45	41	43	39	29	21	20
C-0.05-7	54	44	37	34	31	25	18	18
C-0.05-28	50	51	46	40	31	34	28	23
C-0.05-28-Z	59	55	44	44	37	34	29	24
C-0.15-7	46	52	50	41	32	25	22	20
C-0.15-28	71	57	57	54	46	38	35	27
C-0.15-28-Z	72	62	54	55	45	41	32	29
C-0.20-7	44	46	40	46	30	33	25	24
C-0.20-28	69	46	56	56	43	42	32	30
C-0.20-28-Z	55	59	56	56	44	38	32	29

Note of Case: C = cylinder
0.00, 0.05, 0.15, 0.20 = cane sugar content in %
7, 28 = age of cylinder in day
Z = concrete was poured into the mould after it reached zero slump

Table 4. Ratio of compressive strength at 7 days to 28 days for different water-cement ratio, cane sugar content and age.

Case	Water-cement ratio							
	0,33	0,36	0,43	0,46	0,53	0,56	0,63	0,66
C-0.00-28	0,82	0,81	0,79	0,79	0,70	0,68	0,73	0,75
C-0.00-28-Z	0,79	0,80	0,73	0,67	0,63	0,80	0,98	0,88
C-0.00-28	1,09	0,87	0,80	0,85	1,01	0,74	0,67	0,78
C-0.00-28-Z	0,92	0,80	0,84	0,78	0,84	0,73	0,62	0,74
C-0.00-28	0,64	0,92	0,88	0,76	0,69	0,66	0,62	0,73
C-0.00-28-Z	0,64	0,84	0,92	0,74	0,70	0,62	0,68	0,68
C-0.00-28	0,63	1,00	0,72	0,83	0,71	0,78	0,80	0,80
C-0.00-28-Z	0,80	0,78	0,72	0,82	0,69	0,86	0,78	0,85

CONCLUSIONS

From the experimental results and discussions mentioned above it can be concluded that the application of local cane sugar as concrete admixture will make:

1. significant increase in concrete slump and period of workability,
2. remarkable increase in compressive concrete strength,
3. but does not influence the compressive strength gain.

Therefore local cane sugar can be used as a Type D concrete admixture.

RECOMMENDATION

The experiment discussed in this paper is limited to fresh and hardened concrete properties that commonly need to be determined. The effects of the application of cane sugar on other concrete properties still need further studies. For example is the effect of cane sugar on the concrete durability in the long term.

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